CONSTRUCTABILITY GUIDE

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BACKGROUND

Experienced construction personnel have provided input into construction projects to enhance constructability for many years. Legend has it that Hamid, one of the superintendents building the Great Pyramid, complained to the pharaoh that the blocks coming in were designed so large that installation into their final positions was too difficult, required too many men, led to unsafe work practices, and took too long. He also complained about the cutting of the blocks at the quarry. The blocks were not always true shapes, the surfaces were too rough, and required much rework at the site to make them fit. The blocks also arrived at the site too late. The pharaoh, as a result of these complaints, insisted on an aggressive constructability program. He brought in Hamid to sit down with the designers and the block supplier. The designers were forced to consider rigging and manpower constraints, and accordingly reduced the size of the blocks. The quarry had to improve their quality control and deliver on time.

Further, the ensuing pyramids were installed 13.5% faster at an overall savings of 23.8%. These improvements lasted until the lessons learned were lost and design and construction went back to their old ways (ASCE, 1991).

Constructability was nationally recognized in the mid seventies when it first appeared in "Building and Technology Bulletin", and "Constructability-It Works" (Proctor and Gamble, 1976 and 1977). Then about two years later, an NSF-ASCE (National Science Foundation - American Society of Civil Engineers) study identified constructability, among other topics, as a specific research need for structural engineering (ASCE, 1979). The study pointed out that there is a missing link between design engineers and contractors. For example, problems of constructability of concrete structures occur most often because of the attempt to design slimmer columns. These designs, although satisfying the ACI code, reduce the space for placing concrete, and can create problems in obtaining good vibration.

In 1983, the Business Roundtable's Construction Industry Cost Effectiveness Project (CICE) completed a four year study of how to promote quality, efficiency, productivity, and cost effectiveness in the construction industry. One focus was on constructability, which was summarized in Report B-1, "Integrating" (1982).

Since that time, the Construction Industry Institute (CII) at the University of Texas in Austin was created as a focal point of research into new management methods and techniques to improve the construction industry. In addition, local and regional groups of construction users have been formed, resulting in increased awareness of the benefits to be gained through improved constructability programs. These benefits include improvements in quality and reliability, as well as savings in time and money.

CII's research and publications have been developed primarily for the industrial and commercial construction industry. No formal research has been completed on highway construction by CII or any national organization. A literature search indicates that the state of Texas developed a "Highway Construct*Ability Guide", 1990 and completed some specification changes using the constructability concept. The state of Washington published a technical report titled "Constructability Improvement of Highway Projects in Washington", 1991, where they reviewed and categorized thousands of change orders to identify constructability problems. Since there is no baseline for highway constructability, the CII concepts for the building industry have been adopted in many cases within this text.

The concept of constructability for highway projects is as old as the engineering, design and construction process - it is nothing new. Over the years, many organizations including ADOT practiced elements of a constructability program, but did not give it the name. ADOT submitted plans to Districts for review and conducted field reviews to receive construction feedback. In recent years a Highway Division procedure was published titled "Design Review by Engineering Districts" (Memorandum No. 90-12). This format outlined a review process from pre-design to final completion of the plans.

The topic of constructable plans and the costs associated with resolving problems in the field has been discussed on many occasions. The problem lies in getting people (designers and constructors) from diverse cultural backgrounds and with potentially different goals to work together effectively. A constructability program can provide the mechanism for effectively integrating design and construction - a "common sense" need that has been recognized for a long time (CII). The ADOT 1992/1993 Strategic Partnering Action Plan identified within its issues, the topic of "improving the quality of project plans", Problem 6-6. This Guide and Implementation Plan is a result of that finding.

CURRENT PRACTICES

CII defines constructability as "the optimum use of construction knowledge and experience in planning, design, procurement and field operations to achieve the overall project objectives". The basis of this concept is that experienced construction personnel need to be involved with the project from the earliest stages to ensure that the construction focus and their experience can properly influence the owners, planners, and designers, as well as material suppliers. This does not necessarily mean that the design or project objectives should be changed to meet constructability only from a cost standpoint. Constructability should be used as a design consideration, so that optimum results provide the best of both worlds.

It is common practice in the industrial/commercial industry to develop a project team composed of planners, designers and a variety of construction personnel, whose sole purpose is to review design for constructability issues. CII notes that projects which emphasize constructability have four common characteristics.

- Design and construction managers are committed to the cost effectiveness of the whole project. They recognize the high cost influence of early project decisions.

- These managers use constructability as a major tool in meeting project objectives concerning quality, cost and schedules.

- These managers bring construction aboard early. This means using experienced personnel who have a full understanding of how a project is planned and built, not just people who may be available because they are between jobs.

- Designers are receptive to improving constructability. They think constructability, request construction input freely, and evaluate that input objectively.

THE "REVIEW" FALLACY

The early involvement of construction personnel who are providing feed-back to designers prevents the "review fallacy". This syndrome unfortunately occurs in many organizations, particularly the public sector (CII). This happens when construction personnel are excluded from the planning process and are invited only to review completed or partially completed products from the designer. Comments usually have to be limited to minor details. Scope changes at this point are not feasible because of a variety of reasons, including:

- A significant cost has already been spent on the design. Major changes cause delays and increased expenses.

- The designer is defensive because he has committed himself publicly on drawings and he perceives that a change would affect his credibility.

ADOT has encouraged District participation in the pre-design phase for several years. If sufficient attention is given to the Project Assessment (PA), or Design Concept Report (DCR) by all parties during its development, a majority of the future construction problems can be reduced. Figure 1 illustrates how constructability efforts can result in the largest payoff during the earliest stages of the project.

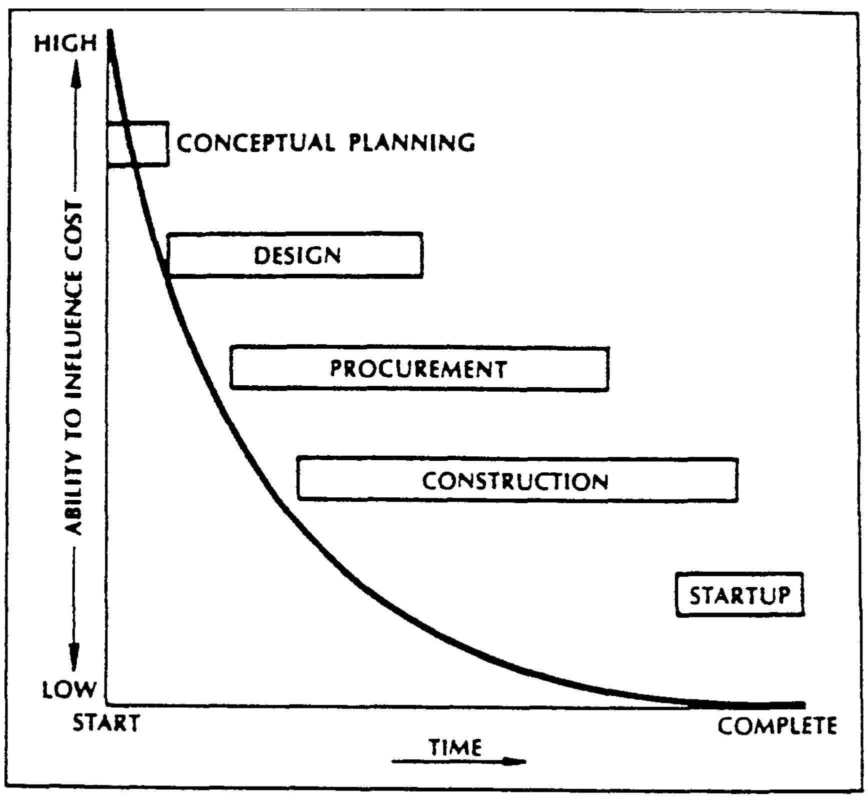

Figure 1. Ability to Influence Final Cost Over Project Life

(Courtesy of Construction Industry Institute)

IDENTIFYING BARRIERS

As with any new concept, there are barriers to implementing a constructability program into an organization. The most common problems which can be expected by the Department are;

- Complacency with the status quo.
- Resistance by designers, who view such efforts as an intrusion.
- Lack of construction experience both in ADOT design and construction personnel.
- Designers perception that "we do it".
- Lack of mutual respect between designers and construction personnel.
- Construction personnel do not respond in a timely manner, and input is too late to be of any value.

BENEFITS

Early constructability efforts result in a significant payback to the project. CII research has cited cost reductions of between 6 and 23 percent, benefit/cost ratios of up to 10:1, and large schedule reductions. The intangible benefits are as important as the quantitative benefits and must be recognized accordingly. These include; more accurate schedules, increased productivity, improved sequence of construction, enhanced quality, decreased maintenance, and a safer job.

CONSTRUCTABILITY VERSUS VALUE ANALYSIS

How does value analysis differ from constructability reviews? Value analysis and constructability can be similar in effect, but differ in both scope and manner of analysis. Value analysis overlaps constructability since its purpose is similar, that is, to achieve the essential functions at the lowest total cost.

Value analysis focuses on function analysis and life-cycle costs, while constructability is achieved by fully exploiting construction experience in a timely and structured fashion. Constructability is most beneficial when performed, prior to establishment of a defined scope, during early planning and design phases. At this time, construction knowledge and experience is least restricted by design decisions, and most capable of affecting the final project (CII).

CONSTRUCTABILITY IMPLEMENTATION GOAL

The Arizona Department of Transportation has endorsed constructability reviews in an effort to improve the total quality of our construction bid package. The Department will optimize the use of construction knowledge and experience in planning and design to achieve the overall project objectives.

In view of our continuing efforts to provide the highest degree of quality and cost effectiveness in our projects, it is the Department's intent to implement constructability to the fullest degree possible. This applies to all phases of project planning and design.

CONSTRUCTABILITY OBJECTIVES

- Enhance Early Planning
- Minimize Scope Changes
- Reduce Design Related Change Orders
- Improve Contractors Productivity
- Develop Construction-Friendly Specifications
- Enhance Quality
- Reduce Delays/Meet Schedules
- Improve Public Image
- Promote Construction Safety
- Reduce Conflicts/Disputes
- Decrease Construction/Maintenance Costs

PHILOSOPHY

Districts will provide input to the planning and design from the standpoint of project intent, constructability, operation and maintenance. This will be accomplished through field reconnaissance with designers and reviews of design documents at various stages of development. Obtaining feedback from maintenance personnel at this point is very important, since they ultimately live with the finished product and are aware of previous construction deficiencies. The reviews will be scheduled during both the Conceptual Development and the Design phases.

Studies show that a majority of change orders and/or construction claims arise from plans and specification associated problems. It is extremely important that a concerted effort be made by the District representatives, to conceptualize the project, understand its problems, and provide thoughtful feedback to the designers. Constructability issues concerning scope and design should be recognized and addressed up front, so that a quality set of plans and specifications are produced. The early active involvement of the District construction representatives will also provide them insight into the design intent. This knowledge will be beneficial during the later construction stage when "minor" field changes are requested by the contractor.

Each project will be assigned a Project Manager in accordance with DOT's "Project Management Process". The team size will vary, depending on the construction work complexity. The organizational chart below shows a basic project team, with help as needed, from other in-house personnel. The chart also allows the option of utilizing "construction specialists" for difficult tasks. These experts could be obtained from a list, composed of people who are experienced in the contracting industry on specific construction operations.

PROJECT TEAM

ADOTTech.Units	**Project Manager**	**Construction Specialists**
• **District Reps.** • **Designers** **Roadway** **Materials** **Bridge** **Traffic** **Environmental** **Right of Way** **Photogrammetry** **Geotechnical** **Other Agencies**		**(As needed for complex projects)** • **Lighting/electrical** • **Forming/false work** • **Welding** • **Pipelines** • **Prestressing** • **Painting** • **Paving-AC/PCCP** • **Bridge Foundations** • **etc.**

The project team should meet to discuss constructability issues throughout the planning/design process. During the development of the Project Assessment (PA), a concerted effort should be made to identify specific constructability items and determine their impact on the conceptual design. The Department appointed Project Manager's role is to assure that constructability issues have been given adequate attention and are resolved. This can be accomplished by holding one or more constructability review sessions, chaired by the Project Manager. The team also may attend the "kick off meeting" held at the start of the design stage.

Follow up meetings can be held at the 30% and 60% design phase of the plans. Special emphasis should be given to the 60% stage, since it involves both the Office and Field Review with the District. Additionally, this may be the last opportunity that any constructability design changes can be considered without major negative impact to the project. The Project Manager determines the amount of time necessary for this constructability review, and whether final review is necessary at the 95% stage.

The formal Department procedures for team development and review will be provided at a future date.

LESSONS LEARNED

It is important to record the changes made and "lessons learned" during the planning, design and construction of the project. Easy reference to this collection of ideas, and/or solutions to problems becomes a valuable tool for future projects. Specific lessons learned should be documented at the time they occur, rather than wait until the end of the design or construction stage. Sources of information at the conclusion of the project may be obtained through; change orders, Final Plans & Specification Reviews, Construction Partnering Closeouts, and personal interviews.

Information regarding these issues can be submitted in writing on a Highway Development Improvement Reporting Form. Within the recommended solution, an assessment of the following factors should be addressed; cost, schedule, quality, safety, and whether any changes of the standard specifications are required. Either construction or design personnel can submit a constructability suggestion. These issues may be summarized and entered into a Continuous Improvement Opportunities database maintained in the Special Programs Section of ADOT. Procedures concerning this topic will be distributed by the Special Programs Section at a future date.

CONSTRUCTION CONCEPTS

The following Construction Concepts have been identified to help during the planning/design stage. These comments should not be considered as a cook book, but are shown to promote thought on the part of the designer or construction personnel. There is no replacement for good engineering judgment, so each case must be considered on its own merit and handled accordingly.

Many of these comments were received from local contracting firms who routinely bid and construct ADOT projects. Some of the suggestions may at first appear to be a contractor problem and not an ADOT concern. A true constructability program, however, must consider all factors to realize the potential benefits of quality and cost savings.

It takes time to design a job that is phased with traffic shifts or other complexities. It also takes time for the constructor to "learn" the job and fully understand the sequencing of operations to build it. This may mean calculating take-off quantities or at least comprehending work needs at various stages throughout the project. Far too often, field personnel have been guilty of glossing over the plans during design reviews, only to later discover those problems in construction.

One last comment - there always seems to be differing opinions between Districts when it comes to materials, methods or design types. Everyone must set aside their personal preferences during this exercise, so that the pure constructability issues can be fully considered.

GENERAL

- Are areas available for; stockpiling processed materials, form laydown & fabrication yards, equipment parking, temporary field offices, personnel parking, and purchased material storage? If areas can be secured without excessive cost during the planning stages, efficiency during construction will improve.

- Will double handling of materials be involved? Is there sufficient space on the project for temporary stockpiling?

- Are relocated utilities shown in their new location on the plans or referenced documents? Are they referenced to the same vertical and horizontal control which will be used by the project?

- When local city plans for utility extensions etc. are included within the ADOT plans set, do they coordinate with the construction operations, is the stationing compatible with the ADOT plans, and are they understandable?

- Are the pay items in the bid tabulation apparent in the specifications and on the plans? If items are combined for payment is it clear in the specifications? Conversely, is all of the required work covered by pay items?

- Are work areas accessible for personnel, material delivery or equipment operation? Difficult access for personnel can negatively impact productivity. In addition, difficult access routes frequently present unsafe working conditions. High volume haul routes with constricted openings or bottle necks can adversely impact cost and schedule. Does trucking have a free flow thru the site, and can it merge safely into traffic? The consideration for accessibility for major pieces of equipment and temporary erection access can be critical. Is access available thru other properties?

- Consider major construction methods that "drive" the design during conceptual planning.

- Will weather or local conditions become a factor for the successful completion of the job?

- Are materials readily available in this locale for the project design requirements?

- Are designs configured to enable efficient construction? The desired result is to have an exchange of ideas between construction and design before the "pencil on paper" design activities occur. The following factors should be kept up front in constructability deliberations. Simplicity is a desirable element of any constructable design. Flexibility for the contractor to select alternative methods of innovative approaches is highly desirable. Sequencing of installation is as much a design consideration as it is a procurement and construction consideration. Designs that require special skills should be minimized in all cases, along with ones that are highly labor intensive (CII).

- Standardize design elements within the project. Both cost and schedule benefits can be realized by standardization if the quantity is sizable. Specific advantages include; increased productivity from repetitive field operations, volume purchase discounts, simplified material procurement, simplified materials management, and reduced design time (CII).

- Investigate the possibilities of allowing access thru the R/W fence with temporary cattle guards on interstate highways, to reduce haul lengths to materials sources.

- Construction efficiency needs to be considered in specification development. Common problem types associated with difficult to construct specifications include; gold-plated designs or specs, unrealistic tolerances and/or requirements, and impractical methods of measurement and payment.

- Constructability is enhanced by the following considerations. The standard specifications offer clear-cut options (the less new spec writing required, the better--and the probability of error and construction rework is diminished). Special Provision development for a project is done as a distinct project activity with full and early involvement of personnel with appropriate construction knowledge and experience. Clarity is sought as one of the prime characteristics of a good specification. The cost saving potential of "or equal" specifications is balanced against the risk involved. The specifications are up to date and conform with latest industry work methods.(CII)

EARTHWORK & GRADING

- Is there heavy brush or light clearing? Is burning allowed-who governs? if there are a substantial amount of trees, can they be sold as merchantable timber? Is there a site where tree stumps can be buried?

- If project is located within federal land, a National Forest, State land or Indian reservations, check local requirements. Are there restrictions on access to site or other sensitive environmental issues?

- Is special treatment of finished slopes required due to environmental and visual constraints from other agencies? Who is to approve the slope treatment and how is it to be paid for?

- Is removal limit for utilities, major landscaping elements and concrete structures etc., clearly indicated on the plans?

- If concrete removal quantity is sizable, is there an available dump site? Will project embankments accommodate waste concrete?

- If removal item is asphaltic concrete (with environmental concerns for waste), can it be incorporated into the job or is there a dumpsite available?

- Will blasting be allowed for removal of structural concrete?

- Is there an available site for stockpiling materials for salvage?

- Define limits for sawcutting. If depth of cut is important, then state minimum or maximum.

- Are asphaltic concrete mill widths compatible with standard equipment sizes? Milling machines normally are 6' or 12.5' in width. Partial width cuts are not feasible due to tooth wear and machine capabilities. Small 12" to 18" machines are available for manholes or minor areas.

- Can materials removed from Grading Roadway for Pavement Item ie., base materials, etc., be used elsewhere on project?

- Is earthwork phasing compatible with the actual construction and traffic control plan of the job? Define the earthwork needs in each stage. Does each stage balance, or does it require borrow or waste? Is the proposed source of embankment available or presently under traffic? Is there a temporary stockpile site on the job for any excess excavation which will be needed for a future stage?

- Does horizontal and vertical alignment create special construction problems, ie., widening on one side of the roadway may be more cost effective that widening on both sides because of physical restrictions.

- Do the driveway, turnouts, or side road vertical grades meet the standards. Have the property owners been contacted and are they agreeable to any significant changes in grade?

- When faced with designing staged construction to accommodate traffic on an existing route, review the local conditions. If the project is in a rural area with minimal conflicts or terrain differences, consider obtaining temporary R/W easements to construct detours around the work sites. This will enhance public safety, the contractors' productivity and the overall job schedule.

- Are shrink and swell factors reasonable? Is there any recent data on similar material in this region? If shrinkable material quantities are significant, consideration should be given to performing insitu field densities at different elevations within the proposed source.

- When earthwork is tabulated for a large project, and it appears that the job will come close to balancing, provide a quantity "cushion" to insure against significant over/underruns which create a changed condition in the field.

- If there is a choice on designing a project with waste or borrow, is this a section within a planned corridor which can be used to balance another project? Can you avoid designing adjacent waste and borrow jobs which do not bid concurrently?

- Which product is most economical to deal with - borrow or waste? Consider local conditions for borrow availability or waste sites. Is waste material dirt or rock? Can the project accommodate the waste quantity with widenings, pullouts, slope flattening, or berms? If additional excavation is needed to balance embankment, can cuts be flattened or daylighted?

- On large earthwork jobs, where it is necessary to haul over existing roadways, designate areas for temporary crossings, or detours so that off highway equipment can be used.

- Consider excavation type for phasing purposes. If job has mix of dirt and rock, what material is available when it is time to finish subgrade? Will it be necessary to import borrow?

- Is drill and shoot required? Will traffic be impacted - what is acceptable length of time for highway closures?

- Are roadway cuts wide enough to accommodate drills and excavation equipment 15'+?

- Are there any impacts on adjacent structures or overhead utilities regarding fly rock? What local laws pertain to the control of fly rock and seismic monitoring?

- Will shallow embankment sections accommodate anticipated rock size? Are there difficult grading operations which can be eliminated?

- It is necessary to overshoot the bottom of rock cuts 6" to meet specification requirements. Where are locations of rock cuts to suitable plating material? Is long hauling required?

- Are widths of roadway widenings compatible with equipment sizes? Most placement/finishing units need widths of 12'+ to operate. Anything less becomes a grading tractor/hand labor activity with high costs.

- Is a source available for shoulder build-up material which meets quality standards? Widen existing roadway cuts if possible to create build-up material.

- Is topsoil plating required? If so, is there an available source - onsite or offsite? If existing surface material is to be stripped and stockpiled, is there an area available within the R/W for storage? Will the existing surface provide the required quantity? Will soil amendments or material screening be needed?

- If slope plating is required, are the slope ratios flat enough to assure reasonable plating with standard equipment?

- Is there enough R/W to construct access to roadway widenings? Can pioneer roads feasibly be constructed into excavation or embankment areas? Can pioneer roads outside of the roadway prism be adequately repaired after construction?

- If pioneer roads are not allowed because of environmental constraints, have alternative means of access been reviewed and verified? Are the constraints clear in the specifications or on the plans?

- Can overloads be hauled thru the project? Is hauling compatible with existing traffic patterns? Are turnaround areas available for trucking? Consider strengthened structures or use temporary overload haul bridges for increased haul efficiency and reduced impact on public streets.

- Any presence of ground water or active streams? What environmental regulations govern? Will pumping or cofferdams be required?

- Try to minimize restricted areas or irregular shapes which are not compatible for subgrade finishing with normal equipment.

BASES & PAVEMENTS

- Minimize low production or hand work areas for placing or finishing.

- Are truck turnaround areas available?

- Can overloads/width be hauled through job or re-routed to take advantage of savings?

- Can permits be obtained to haul over length loads (doubles/triples) to the job in rural areas?

- Consider the use of 100% milled asphaltic concrete for base course material, backfill, or shoulder build-up.

- If possible, avoid roadway widths for widening projects which are not compatible with standard equipment sizes. Anything less than 10-12' in width for base course becomes a grading tractor/hand labor activity. Asphalt paving machines usually have a standard screed width of 10'. Overlapping the mat with the machine is acceptable for short distances, but extended use can lead to uneven screed wear.

- Explore possible haul routes thru metropolitan areas with local authorities prior to advertisement and list alternatives with known restrictions ie., dust control, night hauls, trucking volume, etc.

- Do construction phasing plans and details allow for width of conventional PCCP paving equipment tracks (30-36")?

- Are the material sources required for special materials available for the project and within a reasonable haul distance? If a long haul is required, does the type of material warrant the additional expense to the project? If not, are there alternate materials which can be used?

PIPELINES & DRAINAGE

- Identify all utility conflicts on plans, if possible, by preliminary potholing. Indicate the type of existing pipeline material on the plans, so that its structural support can be considered when new utility crossings are made. Eliminate known utility conflicts prior to construction to avoid delays. Do plans show locations of relocated utilities?

- Is underground work (new storm drains, pipelines, gas, electric, etc.) sequenced to coincide with or enhance construction phasing? If partial construction is required for pipelines, do temporary cut-off locations conflict with proposed traffic patterns? Will facility need to be functional in its temporary condition?

- Are soil conditions conducive for trenching? Will the underlying material require blasting, or is it sand which has an angle of repose flatter than the area available to excavate? Will utility crossings allow open trenching or require boring?

- Are soil conditions compatible with cast-in-place pipe option?

- Are the diameters of the bored or augered pipe sleeves the correct size for existing soil conditions, ie. 8" sleeves versus 12" cobbles?

- Limit the use of "modified" catch basins. Attempt to incorporate the same catch basin standard throughout the project to improve forming productivity and standardize hardware.

- Check catch basin location and depth to assure that no conflicts will occur with new or existing underground utilities.

- Check pipe culvert locations to assure that; there are no utility conflicts, end treatments provide the required erosion protection, and the structure generally fits the drainage site conditions.

- Are new or existing dikes/berms clearly indicated on the plans? On a reconstruct item, should the original slope be flattened? Can each location be accessed with equipment - this is especially critical in large cut areas with minimal R/W. Is suitable dike material (no significant rock) available from the project, or will borrow be required?

- Does a typical section need to be shown for ditch/dike's or channels?

- When designing concrete linings for channels, allow either shotcrete or class S structural concrete as alternate methods.

- Will linings be needed for detention/retention basins? Is soil cement sufficient or will a special product be required? If a patented lining system is specified, will it need the manufacturers expertise for installation?

- Has consideration been given to temporary drainage thru the project during specific construction phases? Do detours need pipe culverts? Will water be inadvertently directed into properties outside of the R/W during the storm season?

- Has the ponding area required on the upstream of the culverts been considered? Is drainage easement needed for possible ponding?

- Has offsite drainage been considered? Are temporary easements needed for drainage construction? Do provisions need to be made to grade behind sidewalks or curb & gutter to meet existing contours?

STRUCTURES

- Do the special provisions fit the job or have they been simply copied from an old not-applicable project?

- Verify screed elevations and check dead load camber diagram for accuracy.

- Can standard equipment be used to drill cassion foundations? Are boulders a potential problem? Use 4' minimum drilled shafts in SGC material. Are special measures needed for inspection?

- Are soil conditions compatible for steel piling? Is pre drilling required? Will piles require a special shoe?

- Is dewatering required for foundation work? Will construction require cofferdams or wet wells and pumps? Consider establishing a bid item force account for dewatering, to reduce the risk cost for unknowns and limit markups on FA to 8%-10%.

- Strive for simplicity in designs to take advantage of constructability savings, ie. adjust alignment if possible for bridges in rural areas, to avoid curves within the structure section.

- Avoid heavily skewed bridges. Lengthening to reduce or eliminate skew should be considered.

- Standardize shapes of piers for bridges on the project to maximize form use.

- Avoid irregular structure shapes if possible, for walls or footings in order to save concrete. The labor cost for forming far exceeds the concrete material value.

- On post-tensioned box girder bridges, make sure that there is sufficient room for the jack and the extension of the ram. Normal procedure is to pour the wingwalls or a portion of them, after post-tensioning the bridge.

- Minimize architectural details, particularly where aesthetics are not a factor. Since most inserts are made of plastic or rubber, standardize the detail when possible, so that costs can be lowered from the additional form reuse.

- Is vibrator space provided around reinforcing steel to avoid honeycomb problems? Does steel spacing meet specification requirements?

- Avoid reinforcing steel congestion in pier caps and hinges, caused by the mats of the deck steel, the cap steel, and the column reinforcement.

- Use uniform heights for retaining walls to maximize the use of gang forms.

- Except for long runs of retaining walls, use two foot minimum steps.

- Consider working area needs during easement procurement. Space is needed adjacent to a major structure for a form laydown site.

- Allow sufficient room between new foundations and existing roadways for the excavation, a working area, and a barrier.

- Does structure site have any overhead utilities which will conflict with operation of cranes? Can the overhead lines be temporarily rerouted, or shut down?

- Can access to structure locations be provided which will permit a free flow for transit mixers or trucking? Is it compatible with traffic patterns and safe to merge? Has pedestrian traffic at the structure location been addressed?

- Design bridges which require falsework construction over traffic conditions, to allow a 16' minimum clearance to the bottom of the falsework. Safety beams for falsework <16' is a high risk item and is constantly receiving traffic hits. Does falsework require illumination for night traffic? Is there a need for pedestrian openings?

- Encourage the use of precast units. If precast girders are used, can they be trucked over the available highway route or is there a load/length problem? Can access be created adjacent to the structure to set and erect the girders? Is it possible to precast the girders on site?

- Consider stay-in-place decking over freeways, railroads, high stream beds, or canals where formwork striping is difficult or requires freeway closures.

- Is special manufacture required for bridge bearings? Are they readily available or a long lead item? Who should inspect the bearings?

- Make sure the plans show that bearings are to be placed on a level bearing surface, and the orientation of the bearing device relative to the centerline of the substructure is clearly stated. A table indicating the amount and direction of offset to account for temperature/shortening movement should be included.

- Sign foundations - conventional truck-mounted drilling equipment has a 6 foot limitation in its ability to reach from the side or back of the truck. Special consideration needs to be given when placing foundations in existing roadways that have steep slopes or other obstacles.

- Verify sign/lighting foundations to assure that they clear all utilities and are out of the sidewalk area.

- Check for utility conflicts and make sure that any requirements for lighting and signing on the structure are shown on the structure plans - not just on the lighting and signing plans.

- Complex slings or bracing systems are often needed to provide temporary support for designed utility ductwork in bridges. Address this need and design the temporary support if required.

TRAFFIC CONTROL PLANS

- Insure that detour design fits field needs. Do planned detour grades and existing ground contours appear to reasonably conform to the existing conditions? Does the detour grade coincide with crossroads elevations? Do the detour ends meet the existing or proposed alignment? Does the detour drain properly to avoid ponding on the pavement?

- Is there enough area inside the detour alignment to perform planned work?

- Consider traffic flow for phased construction of elevated or depressed structures. Is there an elevation difference that will require the use of sheet piling or some other technique to maintain traffic lanes?

- Has access for affected local business or residents been considered while the detour is in use?

- Is the traffic control plan in concert with construction phasing? Check staging to verify that detours or roadway segments will be open for traffic at the designated times.

- Is signing diagram clear and understandable? Does signing meet the traffic needs in each phase? If temporary barrier is required, have all staged moves been accounted for?

- Can traffic conflicts be avoided by constructing temporary over/under passes for hauling equipment in high volume areas?

- Are required lanes and closure periods for freeways and local streets, clearly listed in the plans or special provisions?

- Are work zones sufficient in size for the intended construction operation ie., allow 30"-36" for PCC paver tracks for work operation. Can workers, equipment and material deliveries safely enter/exit work zones?

- Have provisions been made for emergency vehicle travel thru the detour/road closure/lane closure area?

- Can conduit for lighting or signals be installed during construction sequence for alignment shown? Is excavated embankment material suitable for conduit trench backfilling?

- If possible, locate underground utilities to meet traffic control constraints for lanes etc. Assume all trenches to require a backslope when calculating lateral clearance.

- Have utilities been cleared in advance? Has power for temporary lighting/signals been provided?

- Wherever space permits, flare temporary barriers to 30 feet outside roadway edge to reduce the use of sand barrel cushions.

INCIDENTALS

- Riprap - what rock is available in region, angular or rounded? Does it meet the specific gravity and size requirements? Can it be produced on the job, or require hauling or from an offsite source? Is access to each riprap location a problem?

- When riprap involves a long haul, allow an alternate bid for concrete or soil cement lining.

- Guard Rail - is embankment material free of large rock and suitable for post placement? Verify that designed transitions to existing bridges or concrete barrier meet field needs.

- On guard rail reconstruction, steep existing slopes may require using longer posts to provide adequate post embedment. Also check horizontal and vertical alignment to determine if special traffic control measures are needed. If guard rail is to be adjusted at the same location, is temporary concrete barrier required for traffic protection? Is the barrier accounted for in the traffic control plans?

- Fencing requirements are sometimes scattered on different sheets within the plans. If the fence alignment can not be shown in sufficient detail on the plan or paving sheets, consider incorporating a separate fence plan for clarity.

- Is temporary fencing needed to protect worksites near pedestrian routes and residential areas?

- Use standard curb and gutter sections as much as possible. This is particularly important in long unbroken runs, since most contractors will use a curb machine and carry standard slip form shapes.

- Define sidewalk and driveway widths on the plans to avoid conflicts with existing utilities. Verify commercial driveway locations in the field to assure proper accessibility.

- Consider potential concrete supply for jobs with small concrete quantities etc. If there is no local commercial supplier, choices may be restricted to a portable plant or long haul transit mixed.

MAINTENANCE CONSIDERATIONS

- Can the finished product be accessed for routine maintenance ie., debris fence clean-out, grader ditch/berm reshape over high cuts, retaining wall maintenance etc.? Will the designed facility require special equipment or other unusual requirements for maintenance which will increase life cycle costs?

- Make certain that catch basins are not located in curb returns or driveways.

- Design catch basins within roadway limits to fall in the gutter pan. Avoid installation in the travel lane where grill could be a maintenance problem from snow plow hits.

- Consider multiple catch basins when designing drainage in a sag vertical curve section, to help reduce silting problems.

- Confirm with Maintenance the appropriate minimum drainage pipe sizes and maximum lengths for each to permit cleaning out blockages (usually 24" diameter).

- Try to avoid significant changes in grade within a drainage system, which may eventually cause silting problems for maintenance ie., a 5% median grade entering a catch basin with a lateral pipe at 1%?

- Consider replacing a double barrel concrete box culvert with a single span box ie., use 8'x4' in lieu of 2-4'x4'. This would require some redesign of the Standards, but the maintenance savings for clean out would be beneficial. The constructability would also be improved, since the square footage in forming costs would reduce substantially.

- Is drainage properly controlled at the ends of structures, ie. to prevent erosion problems in the abutment areas?

- Does the sidewalk cause ponding at the transitions to the bridge deck?

- Minimize the use of concrete slope paving at abutments whenever possible, to eliminate the constant maintenance problem. Consider instead, low profile retaining walls or extending the span to allow 3:1 slopes.

- Locate controller for signals near power supply to reduce cost and maintenance. Provide conduit for future needs.

- Check locations of junction/pull boxes to ensure that they do not fall in a wheel path of the roadway or driveway.

- Consider flattening embankment slopes whenever possible to eliminate guard rail in higher elevations ie., plowed snow collects at guard rail locations causing maintenance problems during freeze/thaw.

- When designing/constructing debris fences upstream of structures, provide maintenance access and a clear sight for visual inspection from the highway.

- Review driveway designed profile, to assure that grade breaks can be negotiated by a vehicle without bottoming out.

- Make certain that traffic signal or light poles are not located in sidewalk area or wheel chair ramp. Is pedestrian push button within reach of disabled?

CONSTRUCTABILITY CHECKLIST

GENERAL

( ) Provide work areas when practical.

( ) Verify utility locations on plans.

( ) Assure utility construction coordination with other Agencies.

( ) Are pay items in the bid tabulation covered by the specs?

( ) Is all of the required work covered by pay items?

( ) Provide access to work areas.

( ) Consider access for routine maintenance in design.

( ) Consider construction methods that "drive" the design.

( ) Is weather a factor?

( ) Are materials available?

( ) Keep design simple and flexible.

( ) Standardize design elements.

( ) Do specifications allow work efficiency?

( ) Are specifications clear, and conform with current practices?

EARTHWORK & GRADING

( ) Clear & grub - how will brush/trees be disposed of?

( ) Check local Agency requirements for environmental issues.

( ) Is special slope treatment required - how is it paid?

( ) Are structure removal limits clearly shown?

( ) Review disposal alternatives for PCC/AC concretes.

( ) Is blasting allowed?

( ) Any available stockpiling sites?

( ) Are sawcutting limits specified?

( ) Do AC removal widths concur with equipment capabilities?

( ) Can existing roadway materials be salvaged for other use?

( ) Is earthwork phasing compatible with construction requirements?

( ) Can easements be economically obtained for temporary detours?

( ) Do driveway/turnout grades meet allowable standards?

( ) How is shrink/swell factor applied to earthwork tabulation?

( ) Are shrink/swell factors reasonable?

( ) Provide quantity cushion on large earthwork jobs.

( ) Attempt to balance between several projects on corridor work.

( ) Which material is more economical - borrow or waste?

( ) Designate temporary crossings for overloads.

( ) Consider material type available during staged construction.

( ) How long of period can highway be closed for blasting/clearing?

( ) Are rock cuts wide enough to accommodate equipment?

( ) What are local laws regarding blasting?

( ) Will excavated rock fit into available fills?

( ) Is satisfactory plating material available for rock cuts?

( ) Are roadway grading/fill widths compatible with equipment size?

( ) Is local source available for shoulder build-up material?

( ) Is there a source available which will meet topsoil specs?

( ) Are slopes for plating flat enough for conventional equipment?

( ) Can access be constructed to remote locations?

( ) Consider overload hauling thru job for large volumes.

( ) Any presence of ground water or active streams?

( ) Minimize restricted areas that eliminate normal equipment use.

BASES & PAVEMENTS

( ) Minimize low production or hand work areas.

( ) Are truck turnaround areas available?

( ) Can overloads/widths be hauled through the job?

( ) Permits for overlength loads to the job feasible?

( ) Use 100% milled AC for base course, backfill or shoulders?

( ) Design widenings which will accommodate standard equipment.

( ) Check out haul routes thru metropolitan areas - restrictions?

( ) Do phasing plans allow for PCCP equipment clearance?

( ) Are special material sources available and reasonable in haul?

PIPELINES & DRAINAGE

( ) Identify utility conflicts on plans.

( ) Is underground work sequenced with roadway operation?

( ) Are soil conditions conducive for trenching?

( ) Is cast-in-place pipe compatible with soil type?

( ) Are pipe sleeve diameter sizes compatible with existing soil?

( ) Consider the use of multiple catch basins in sag vertical curves.

( ) Try to standardize catch basins for the job.

( ) Check for catch basin conflicts with underground utilities.

( ) Keep catch basin location in gutter pan.

( ) Compare roadway/pipe grades to insure cover.

( ) Do designed grades of drainage system encourage silting?

( ) Do dikes/berms fit field needs and can they be accessed?

( ) Are typical sections shown for dikes or channels?

( ) Allow alternates for channel lining designs.

( ) Will linings be needed for detention/retention basins?

( ) Review potential drainage problems thru temporary construction.

( ) Has ponding area on upstream end of culverts been considered?

( ) Has offsite drainage been considered (beyond const. limits)?

( ) Is drainage properly controlled at the ends of structures?

( ) Does sidewalk pond water at transition to bridge deck?

( ) Confirm minimum pipe sizes with Maintenance for clean out work.

STRUCTURES

( ) Do Special Provisions fit the job?

( ) Verify screed elevations and dead load camber for accuracy.

( ) Will cassion drilling require special measures?

( ) Are soil conditions compatible for steel piling?

( ) Is dewatering required?

( ) Strive for simplicity in bridge design.

( ) Avoid heavily skewed bridges.

( ) Standardize pier shapes for job.

( ) Avoid irregular shapes for walls of footings.

( ) Provide sufficient room for jacking P/T bridges.

( ) Minimize architectural details.

( ) Allow for vibrator space around rebar.

( ) Reduce rebar congestion at pier caps.

( ) Design uniform heights when possible for retaining walls.

( ) Use two foot minimum steps for retaining walls.

( ) Consider working areas needs around structures.

( ) Check for overhead utility conflicts.

( ) Consider access to structure site.

( ) Does falsework over traffic provide 16' clearance?

( ) Use precast units when possible.

( ) Use stay-in-place decking when striping is a problem.

( ) Do bridge bearings require special manufacture?

( ) Show clear installation procedures in the plans for bearings.

( ) Minimize the use of concrete slope paving at abutments.

( ) Consider existing terrain when locating sign foundations.

( ) Check sign/light foundations on bridges for utility conflicts.

( ) Is design required for temporary utility ductwork support?

TRAFFIC CONTROL PLANS

( ) Insure that detour design fits field needs.

( ) Does detour allow enough area for planned work?

( ) Consider staged const.- vertical elev. diff. for traffic lanes.

( ) Check access for local business/residents.

( ) Is traffic control plan coordinated with job phasing?

( ) Does signing meet traffic needs in each phase?

( ) Can traffic conflicts be reduced by innovative haul roads?

( ) Is freeway closure information clearly shown in plans?

( ) Are work zones large enough for equipment access?

( ) Can emergency vehicles travel thru zone without delays?

( ) Does required conduit installation fit construction staging?

( ) Design underground utilities if possible to fit traffic needs.

( ) Is power for temporary/permanent utilities available?

( ) Check pull box locations in relation to wheel paths.

INCIDENTALS

( ) What is available locally for rip rap materials?

( ) Is existing embankment suitable for guard rail posts?

( ) Design flatter slopes to eliminate guard rail in snow country.

( ) Is fencing plan clear and understandable?

( ) Is temporary fencing needed to protect worksites?

( ) Is debris fence visible and accessible from roadway?

( ) Use standard curb and gutter sections whenever possible.

( ) Check driveways/sidewalks for conflicts with utilities.

( ) Consider possible concrete supply for small remote jobs.

( ) Can temporary barrier be flared 30' to eliminate sand barrels?

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